National Security Education Center

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Information Science and Technology Seminar Speaker Series

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Patch Foveation in Nonlocal Image Filtering

Wednesday, December 2, 2015

3:00 - 4:00 PM

TA-3, Bldg. 1690, Room 102 (CNLS Conference Room)

Abstract: When we gaze a scene, our visual acuity is maximal at the fixation point (imaged by the fovea, the central part of the retina) and decreases rapidly towards the periphery of the visual field. This phenomenon is known as foveation. To form a complete image of the scene, the human visual system (HVS) typically processes a multitude of foveated retinal images gathered at different fixation points. In this talk we look at the analogies and connections between this feature of the HVS and modern nonlocal (NL) image filters. NL filters rely on the assumption that natural images contain a large number of mutually similar patches at different locations within the image: similar patches are first identified, and then used into adaptive weighted averages or more sophisticated nonlinear shrinkage. Such approach is at the core of several of the most effective image restoration methods to date. Crucial elements in the design of NL filters are the metric or distance used for assessing the patch similarity, and the size of the patch. Large patches guarantee stability of the distance with respect to degradations such as noise; however, the mutual similarity between pairs of patches typically decreases as the patch size grows. Thus, a windowed Euclidean distance is commonly employed to balance these two conflicting aspects, assigning lower weights to pixels far from the patch center. Choosing a metric for patch similarity corresponds to assuming a specific model for describing natural images and their self-similarity: the effectiveness of NL methods depends strongly on the validity of such underlying model. We particularly investigate a different form of self-similarity: the foveated self-similarity. Foveation here corresponds to a spatially variant blur operator, characterized by blur kernels whose bandwidth decreases with the spatial distance from the patch center. In contrast with the conventional windowing, which is only spatially selective and attenuates sharp details and smooth areas in equal way, patch foveation provides selectivity in both space and frequency, mimicking the HVS inability to perceive details at the periphery of the center of attention. Throughout the talk, we adopt the image denoising problem as a simple means of assessing the effectiveness of descriptive models for natural images. We show that, in nonlocal image filtering, the foveated self-similarity is far more effective than the conventional windowed self-similarity. To facilitate the use of foveation in nonlocal imaging, we present a general framework for designing foveation operators, i.e. linear operators producing foveated patches by means of spatially variant blur. Within this framework, several parametrized families of foveation operators are demonstrated, including anisotropic ones. Strikingly, the operators enabling the best denoising performance on complex natural images are the radial ones, in complete agreement with the orientation preference of the HVS.

Biography: Alessandro Foi received the M.Sc. degree in Mathematics from the Università degli Studi di Milano, Italy, in 2001, the Ph. D. degree in Mathematics from the Politecnico di Milano in 2005, and the D.Sc.Tech. degree in Signal Processing from Tampere University of Technology, Finland, in 2007. He is currently an Academy Research Fellow with the Academy of Finland, at the Department of Signal Processing, Tampere University of Technology, where he is also Associate Professor. His research interests include mathematical and statistical methods for signal processing, functional and harmonic analysis, and computational modeling of the human visual system. His recent work focuses on spatially adaptive (anisotropic, nonlocal) algorithms for the restoration and enhancement of digital images, on noise modeling for imaging devices, and on the optimal design of statistical transformations for the stabilization, normalization, and analysis of random data. He is a Senior Member of the IEEE, Member of the Image, Video, and Multidimensional Signal Processing Technical Committee of the IEEE Signal Processing Society, and an Associate Editor for the IEEE Transactions on Image Processing and for the IEEE Transactions on Computational Imaging.

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